An Investigation of 2 m Temperature Biases and their Evaluation in GMAO's GEOS-5 Systems

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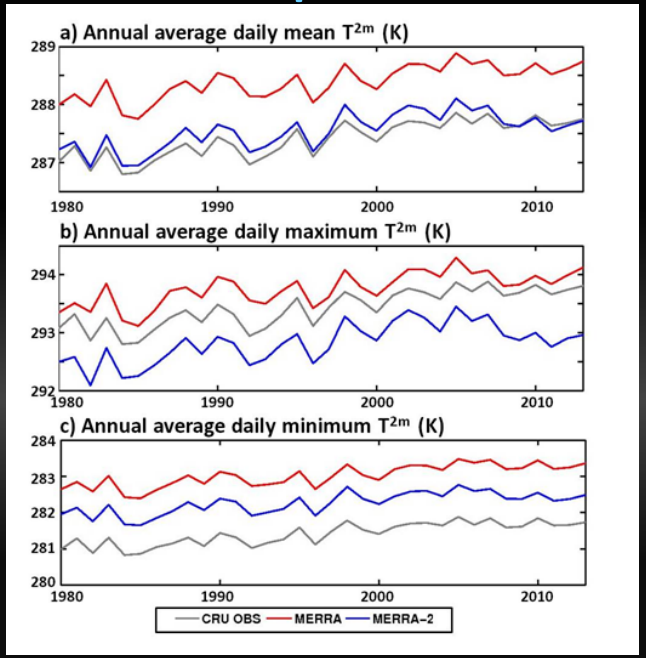
Outline

- Overview of 2 m temperature (T2M) biases in GEOS systems over land
- Summertime warm bias and observation corrected precipitation
- Wintertime cool bias
  - Snow
  - Desert (West Africa)
- Efforts from the modeling team
  - Ground heating
  - Radiation scheme

GEOS-5 Generally Produces Reliable 2 m Temperatures

- However there are consistent biases across GEOS configurations
  - Diurnal
  - Seasonal
  - Regional/Land cover

- That can have implications on
  - Energy budget
  - Numerical weather prediction



Time series of annual average temperature over land
(Provided by Clara Draper)

GMAO Focused Evaluation of T2M

- T2M is an interpolation between surface temperature and temperature at the lowest model level

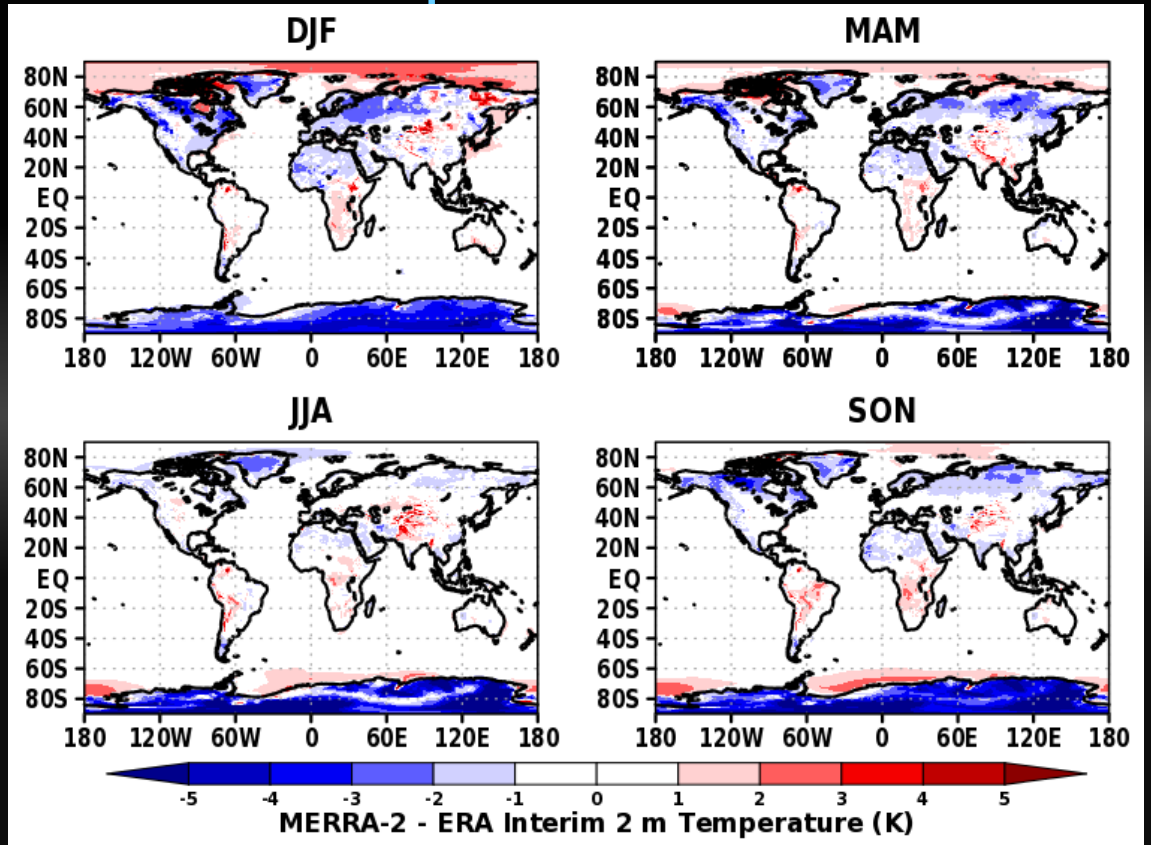
$$\text{Sfc } \Delta T = \text{Qnet} - \text{Sensible Heat Flx} - \text{Latent Heat Flx} + \text{Ground Heat Flow}$$

$$\text{Qnet} = (\text{Downwelling SW} + \text{Upwelling SW (albedo)}) + (\text{Downwelling LW} - \text{Upwelling LW})$$

Substituting the GEOS-5 expressions for each of these fields gives:

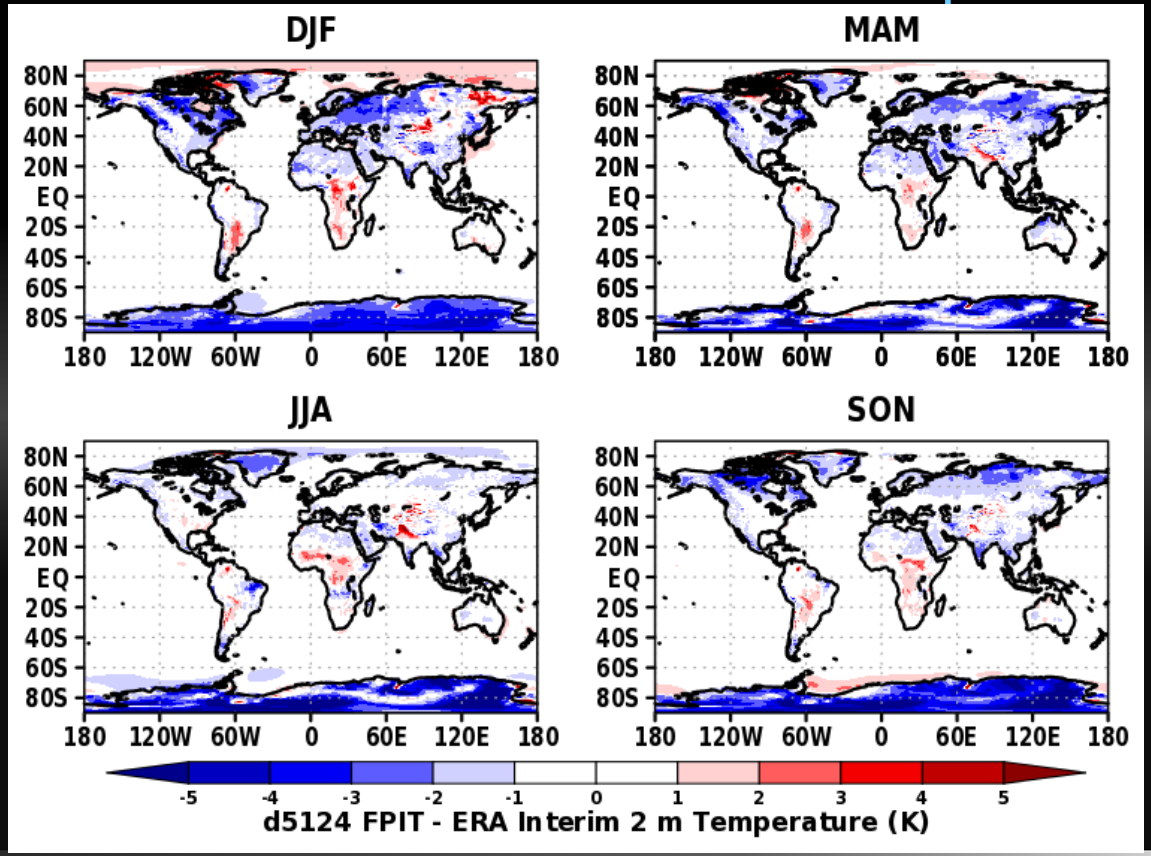
$$\text{Sfc DeltaT} = (\text{swgdn} + (\text{swgdn} - \text{swgnt})) + (\text{lwgdn} - (\text{lwgdn} - \text{lwgnt})) - \text{hflux} - \text{eflux} + \text{ghland}$$

Global Temperature Bias of MERRA-2 Relative to ERA-I



- Seasonal average from 1980-2015
- ERA-I analyzes 2 m temperature
- Ignore Antarctica -> ERA-I is too warm
- Noticeable cold bias in Northern Hemisphere midlatitudes during DJF

Observation Corrected Precipitation Helped in MERRA-2

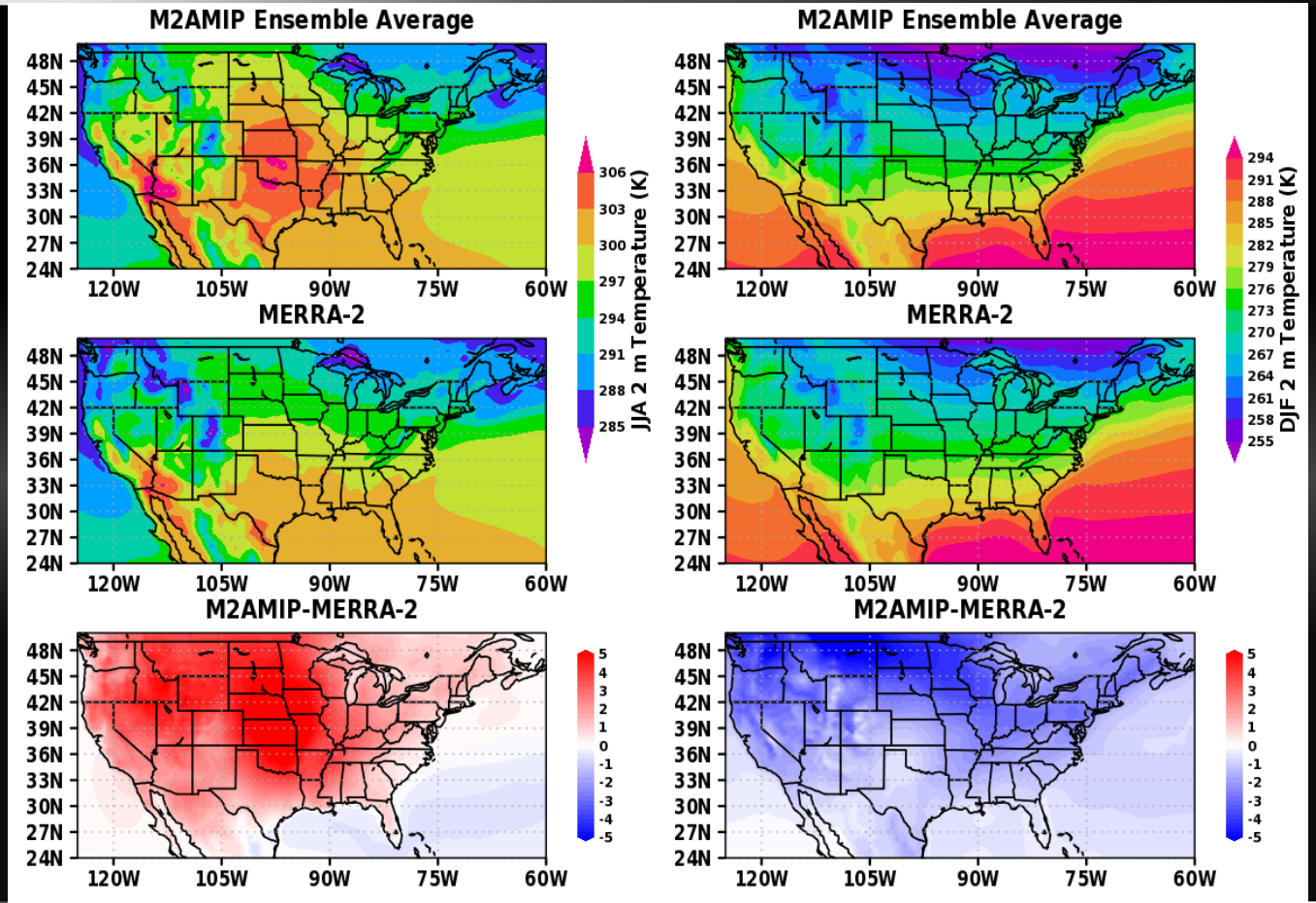


…but is not used in FP or FPIT

- Seasonal average for 2000-2015
- Warm bias in central Africa, South America (Argentina)
- Cold bias in Brazil during JJA

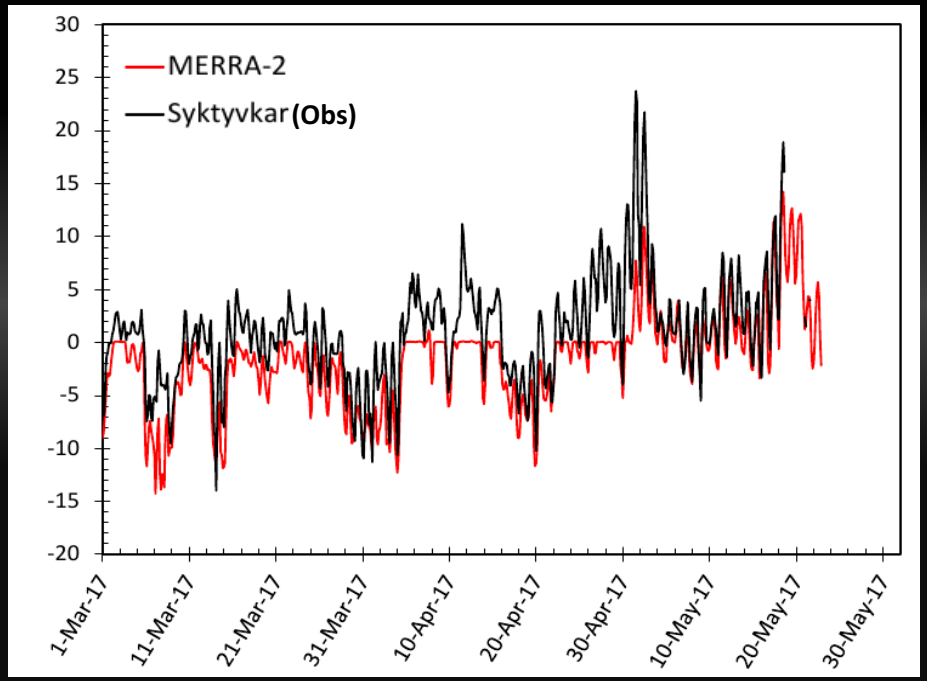
Model Biases with Respect to an AMIP Ensemble

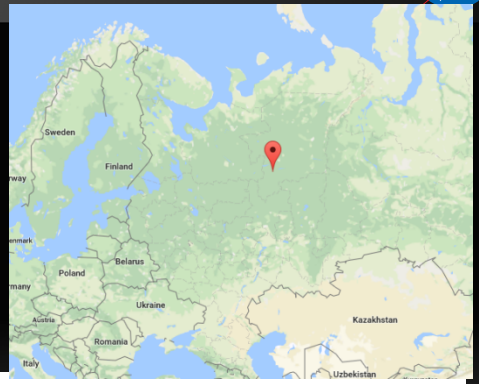
- An energy budget analysis revealed
  - DJF -> surface downwelling LW
  - JJA -> surface downwelling LW + balance between LH and SH

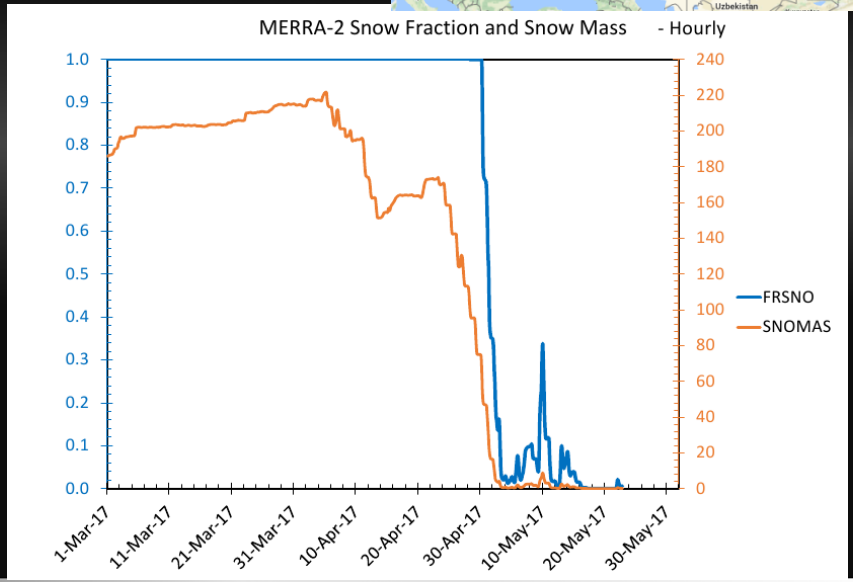


Cool Bias over Snow: T2M Capped at 0 °C

3 Hourly 2 m Temperature

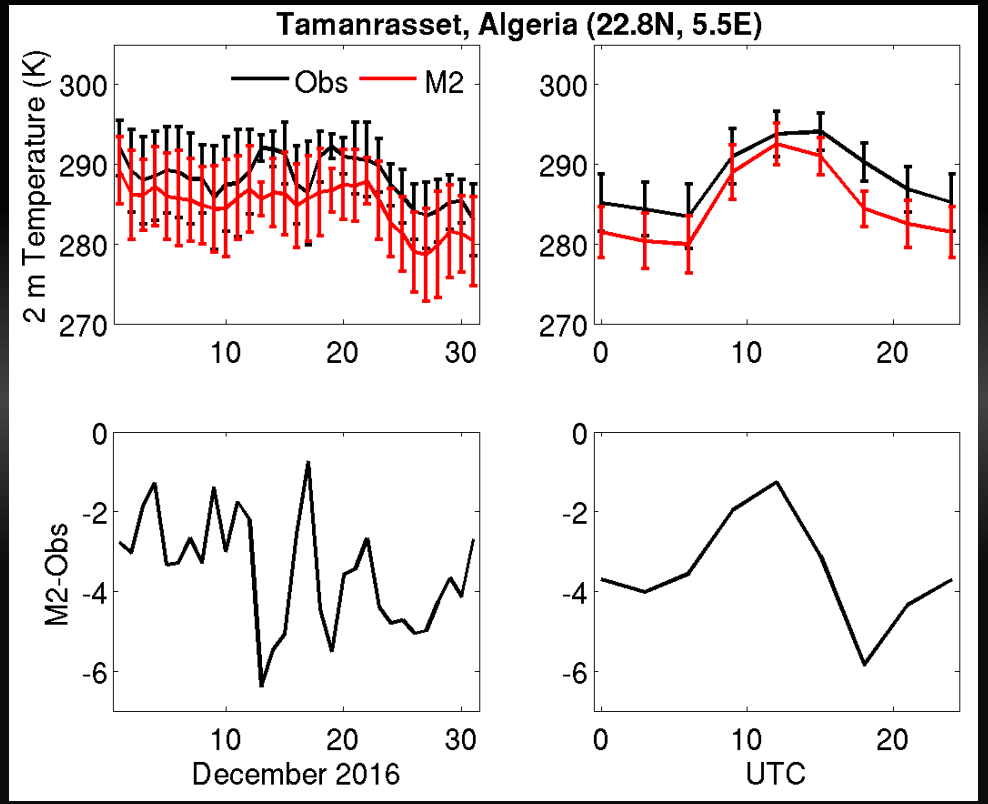






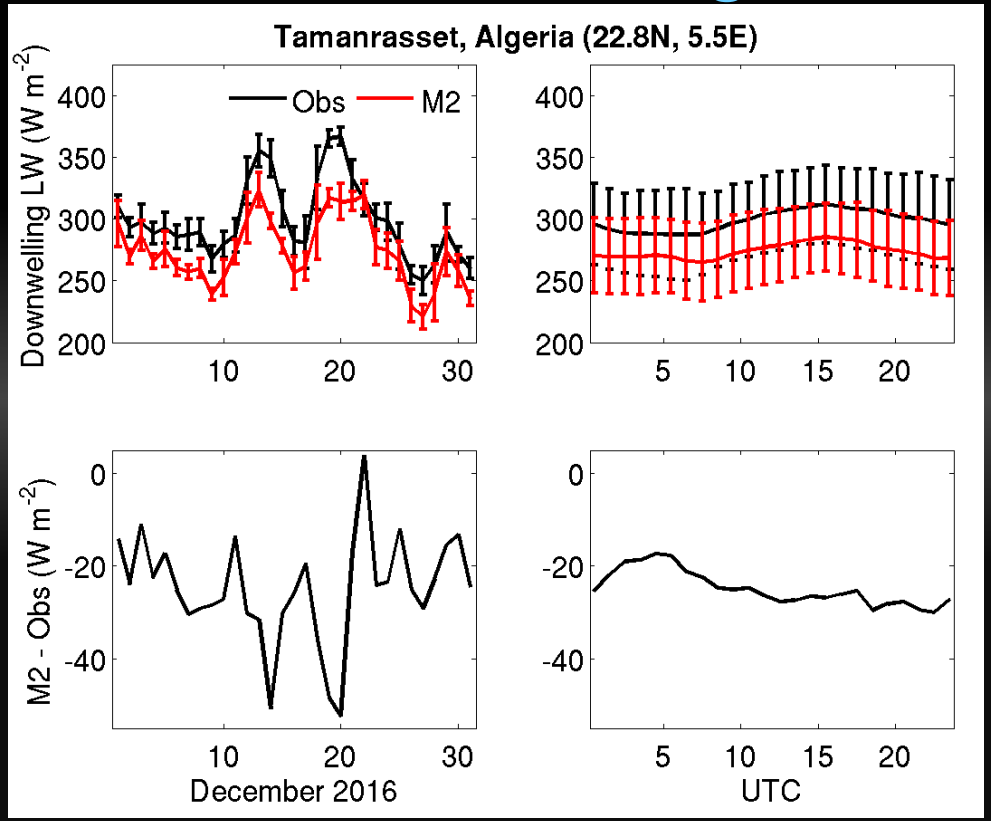
Wintertime Cool Bias in West Africa

BSRN station no: 42; Surface type: desert, rock; Topography type: flat, rural;



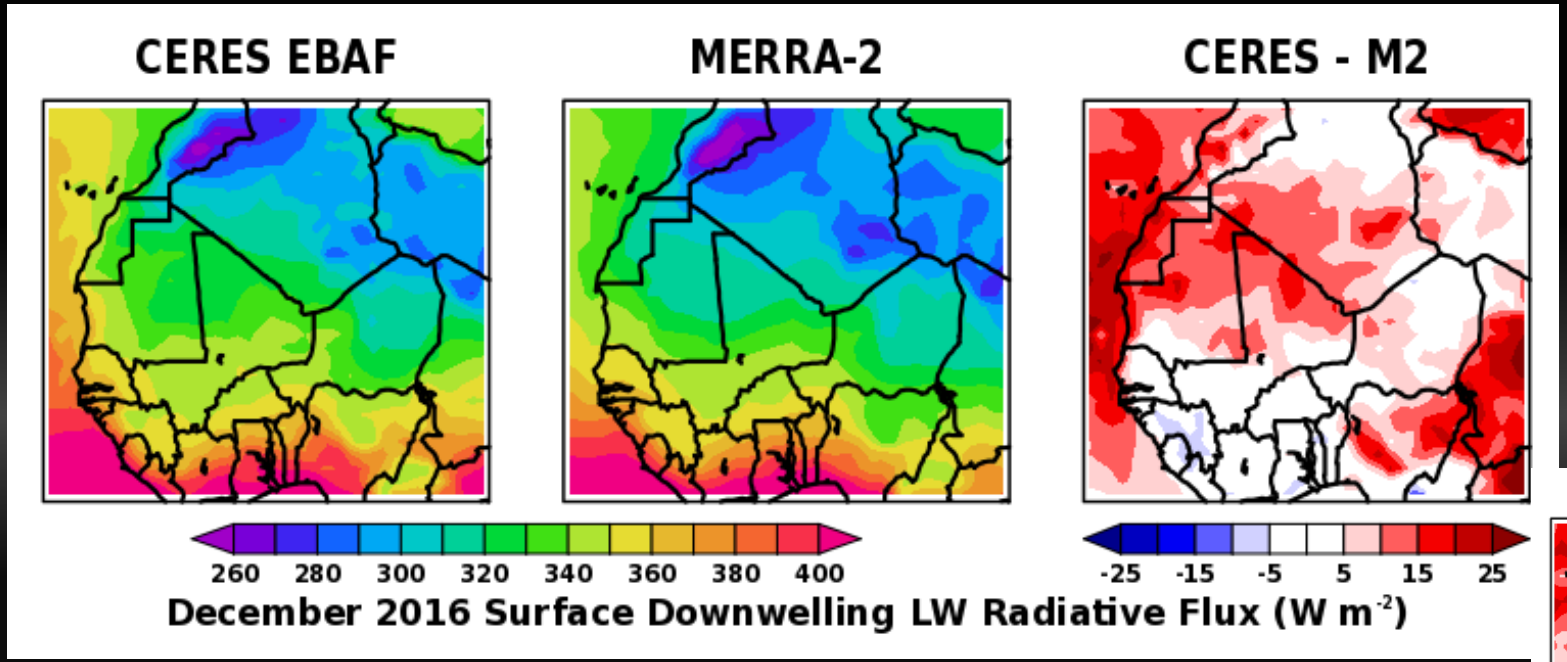
- Consistent cold bias in daily mean and throughout diurnal cycle
- Largest bias at 18z
- 2K difference in diurnal amplitude
- A back of the envelope calculation using the Stefan-Boltzmann law indicates we are looking for ~30 W m^{-2} difference in the energy budget for a 4 K bias

Downwelling LW Radiation in Algeria

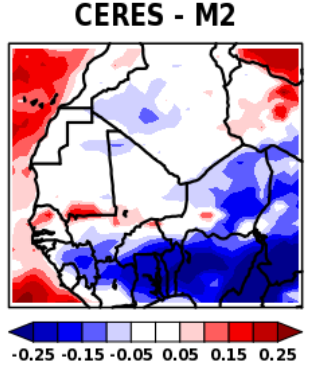


- Mix of clear and cloudy (spikes) conditions
- Consistent bias of ~20 W m^{-2}
- SW radiation is okay!

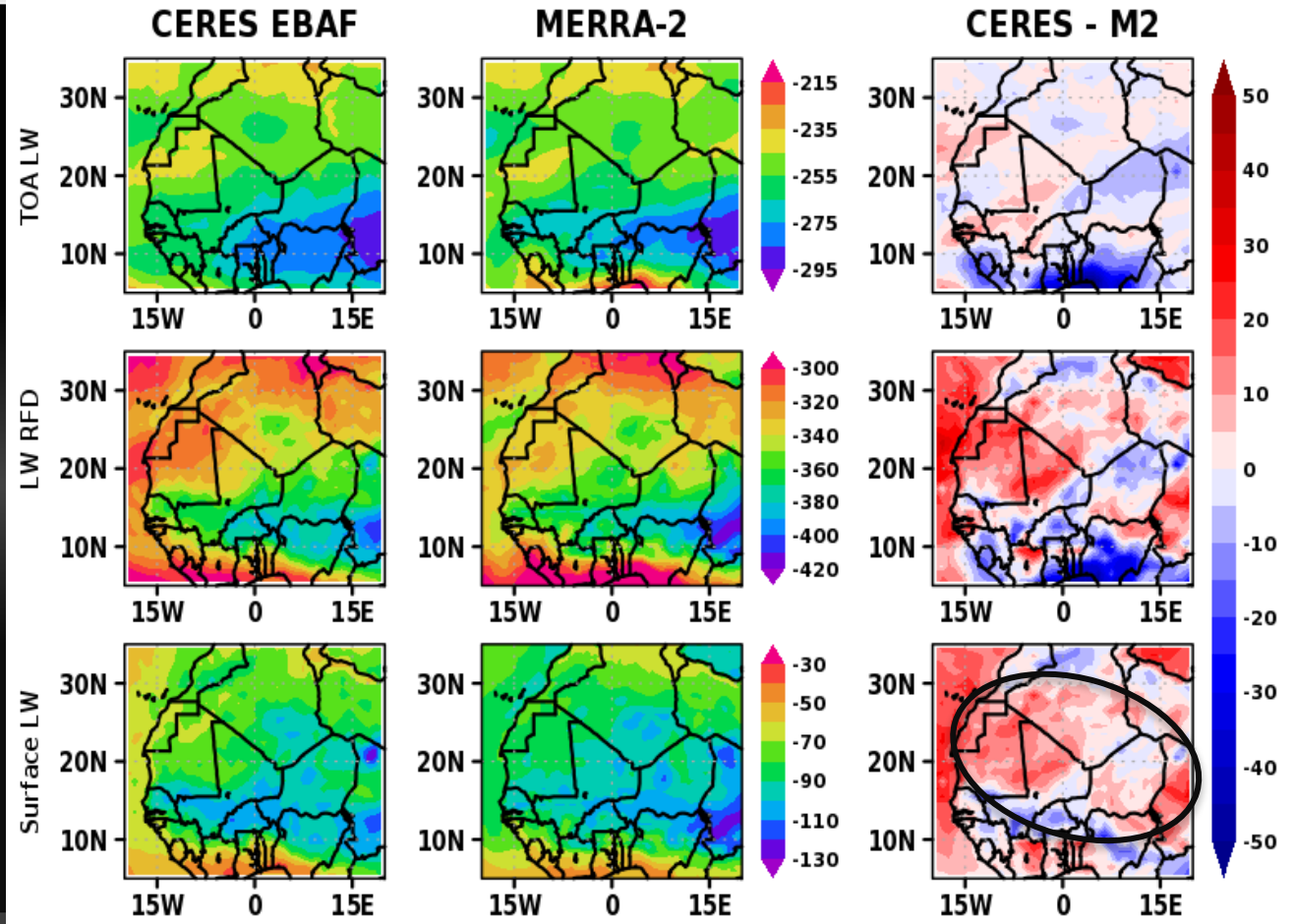
Does this hold for the rest of West Africa?



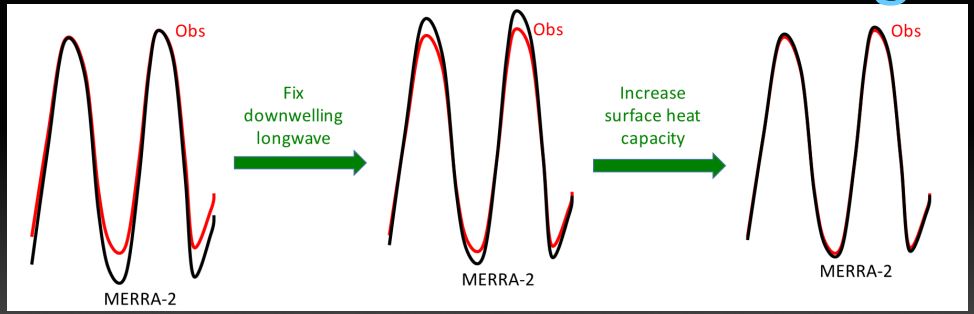
Cloud Fraction



*GEOS-5 temperature and humidity profiles, and well as skin temperature are used to produce CERES EBAF!


CERES EBAF
MERRA-2
CERES - M2
TOA LW
LW RFD
Surface LW
30N
20N
10N
15W
0
15E
-215
-235
-255
-275
-295
-300
-320
-340
-360
-380
-400
-420
-30
-50
-70
-90
-110
-130
50
40
30
20
10
0
-10
-20
-30
-40
-50
December 2016 All Sky LW Radiation Budget (W m^{-2})

Efforts from the Modeling Team at GMAO: Ground Heating

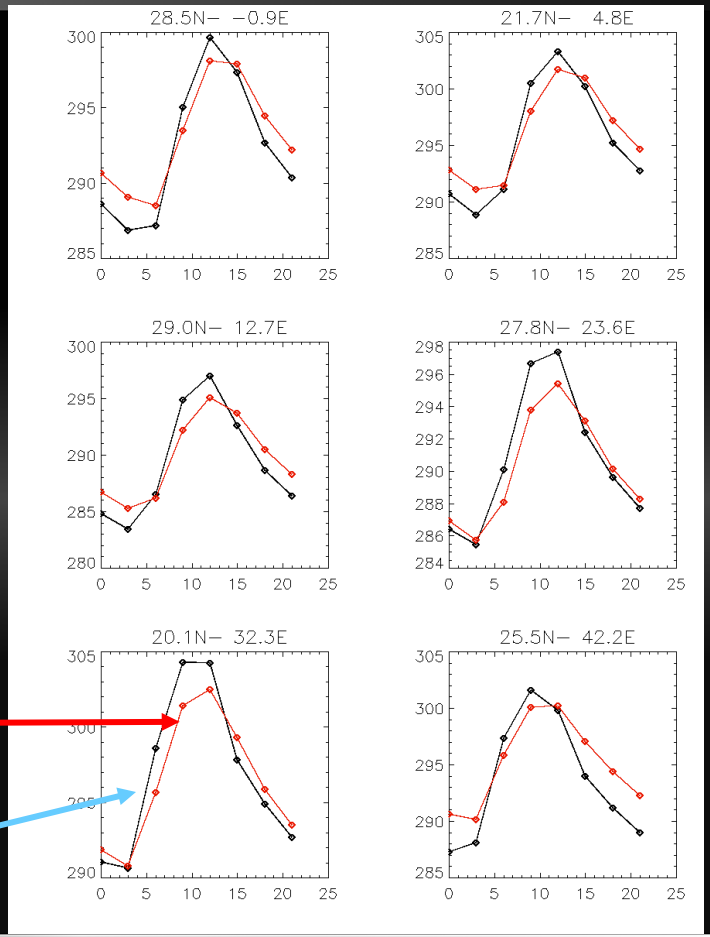


Mean diurnal cycle of 2 m temperature in November for 6 desert points

- Each cycle built from 7 Novembers within AMIP runs

Red: Land surface model with various modifications, particularly an increase in the heat capacity associated with the "skin" temperature.

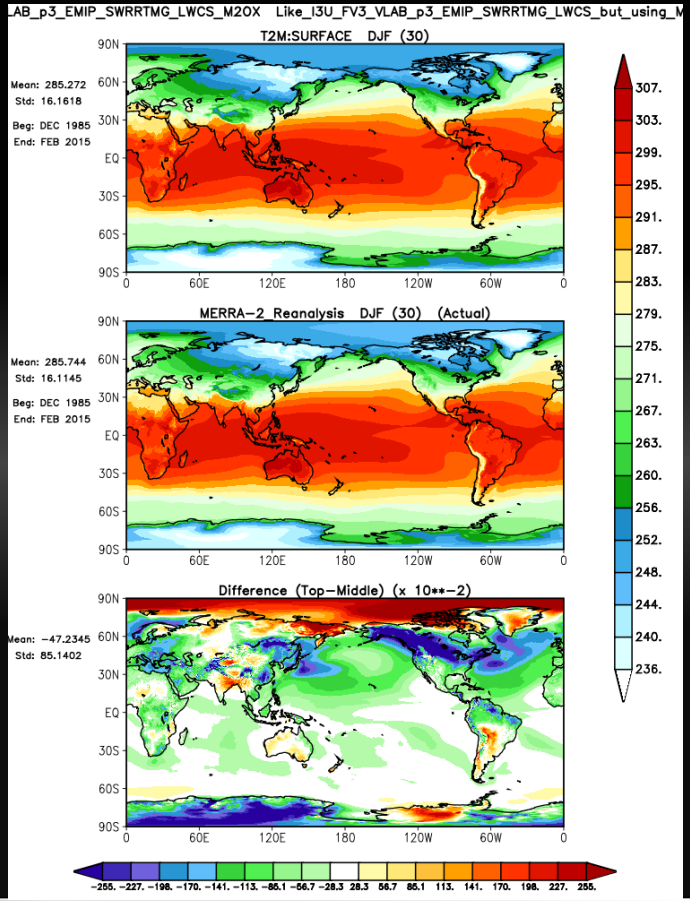
Black: Control land surface model



Efforts from the Modeling Team at GMAO: Radiation Transfer

- Current radiation scheme is Chou-Suarez
- Moving towards RRTM-G
- RRTM-G SW currently implemented in EMIP test cases
- Very much a work in progress

Comparison of 2 m temperature in MERRA-2 and an EMIP with RRTM-G SW →



Thanks!

Take Home Messages:

- We have a focus team that has been working to diagnose biases in 2 m temperature
- Attention has been given to the cold bias over desert areas, particularly West Africa
- Not enough surface downwelling LW radiation
- Increasing the heat capacity of the surface seems to have helped with the diurnal amplitude in temperature
- Ongoing efforts include a fix for the near surface temperature over snow and implementing RRTM-G